Herd Immunity/Herd Infection: Cultural Artifacts of Marginalization and the Dynamics of AIDS

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Abstract

We examine social conditions under which high prevalence of infectious disease can become endemic within a community, in effect constituting a state of 'herd infection' inverse to epidemiological herd immunity. For something like AIDS, under such a circumstance, a single behavioral lapse or adverse accident will probably be a death sentence.

1 Introduction

The form of a social network and the behaviors of those within it are cultural artifacts reflecting both current conditions and historical trajectory: Culture is both dynamically and historically configured, and represents a third system of human heritage beyond the genetic and biochemical epigenetic (e.g., Boyd and Richerson, 2004; Richerson and Boyd, 2005; Jablonka and Lamb, 1995). Here we will examine the role of marginalization and oppression in creating a kind of superhighway for pandemic infection within affected communities, and use a formal model to explore the insight of L. Beane (2011) that a kind of mirror image to epidemiological herd immunity might be possible, i.e., a 'herd infection' sufficient to virtually guarantee the infection of susceptible individuals within a population.

The argument we pursue has two sections. The first focuses on conditions under which a 'giant component' emerges within a networked population of sucseptibles allowing the propagation of infection to a significant fraction of it. The second involves the production of 'risk behaviors' for infection within that population. It will be seen that social network structure and the generation of a 'behavioral vocabulary' that may accelerate infection transmission are not only

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intertwined but synergistic, and strongly determined by current and historical power relations between groups.

This is, overall, quite straightforward, and leads directly to Beane's concept of herd infection.

2 Epidemic threshold and social network structure

The basic idea of herd immunity is that there is a threshold of vaccination for a population above which an infectious disease cannot propagate. Typically, for diseases like measles, chickenpox, and diphtheria, 85-95% vaccination rates prove sufficient to prevent chains of infection within a general population, thus protecting unvaccinated individuals (on the whole) from the diseases. A classic model based on differential rate equations can be found in many places (e.g., Bailey, 1975). The underlying assumption of the model is that probability of contact between individuals is random. Nonrandom contact patterns do not necessarily show similar dynamics, for example if nonvaccinated individuals are all closely connected, e.g., members of a particular political, religious, or other subgroups that interact regularly. This insight can be made in a formal manner by considering social network topology.

Some fifty years ago Erdos and Renyi (1960) explored the emergence of a highly interconnected 'giant component' in random networks. Following the review by Spenser (2010) closely (see, e.g., Boccaletti et al., 2006, for more detail), assume there are n network nodes and e edges connecting the nodes, distributed in a uniform probability distribution – no clustering. Let $G[n, e]$ be the state when there are e edges. The central question is the typical behavior of $G[n, e]$ as e changes from 0 to $(n-2)!/2$. The latter expression is the number of possible pair contacts in a population having n individuals. Another way to say this is to let $G(n, p)$ be the probability space over graphs on n vertices where each pair is adjacent with independent probability p. The behaviors of $G[n, e]$ and $G(n, p)$ where $e = p(n-2)!/2$ are asymptotically the same.

Parameterize as $p = c/n$. The graph with $n/2$ edges then corresponds to $c = 1$. The essential finding is that the behavior of the network has three sections. If $c < 1$ all the linked subnetworks are very small. If $c = 1$ there is a single large interlinked component of a size $\approx n^{2/3}$. If $c > 1$ then there is a single large component of size yn where y is the positive solution to the equation

$$\exp(-cy) = 1 - y.$$

Then

$$y = \frac{W(-c/\exp(c)) + c}{c},$$

where W is the Lambert W function.

The solid line in figure 1 shows y as a function of c, representing the fraction of network nodes that are incorporated into the interlinked giant component. To the left of $c = 1$ there is no giant component, and large scale transmission of infection is not possible. The role of vaccination in a random population is to drive c below that limit.

The dotted line, however, represents the fraction of nodes in the giant component for a highly nonrandom social network, a star-of-stars-of-stars (SoS) in which *every node is directly or indirectly connected with every other one*. In such a case there is no threshold, only a single giant component: Introduction of infection to any node of the network produces infection across the entire network.

The essential argument is that, for the SoS network and analogous topologies, once disease has been introduced into the community, any individual 'risk behavior' interaction with the network guarantees infection, the precise inverse of herd immunity, as Beane has speculated.

Are there any SoS-like networks in the real world? Carol Stack's (1974) book *All Our Kin: Strategies for Survival in a Black Community* describes underlying mechanisms of resource sharing and obligation that necessarily include patterns of intimate contact between sexes. A more recent paper by Murrill et al. (2008) examines a similar network within gay and transgender African-Americans that had been described in the documentary film *Paris is Burning*. The House Ball community "...is rooted in Black traditions of communal social support in response to economic and social exclusion. It functions as a kinship system that is organized to meet the needs of its members for social solidarity and mentoring...". Of the 504 study participants, nearly one-fifth were HIV-positive, some three-quarters of these individuals unaware of their infection status.

3 Marginalization and behavioral coding

Wallace et al. (1996) explore a mathematical model in which 'risk behaviors' for infection constitute essential components of a behavioral code for the transmission of information within the noisy channel of a marginalized community's social networks. The code's form, including the incorporation of risk behaviors, arises as a direct consequence of the external oppressive forces which structure marginalization. This perspective contributes to an explanation for the rapid transmission of infection along a social network. Further, in the face of 'behavioral' interventions, if risk behaviors are parts of a behavioral code for the transmission of group norms, statements of individual worth or resource sharing, then high rates of relapse are inevitable, given the persistence of the external oppression that gives those behaviors symbolic value. Wallace et al. found that violent acts in particular may emerge as key behavioral symbols for sending a message in socially disorganized communities, creating further social disorganization in a destabilizing positive feedback. They call for comprehensive, multifactorial reform to reverse the effects of continuing economic and social constraints or public policies of 'planned shrinkage' and 'benign neglect' and

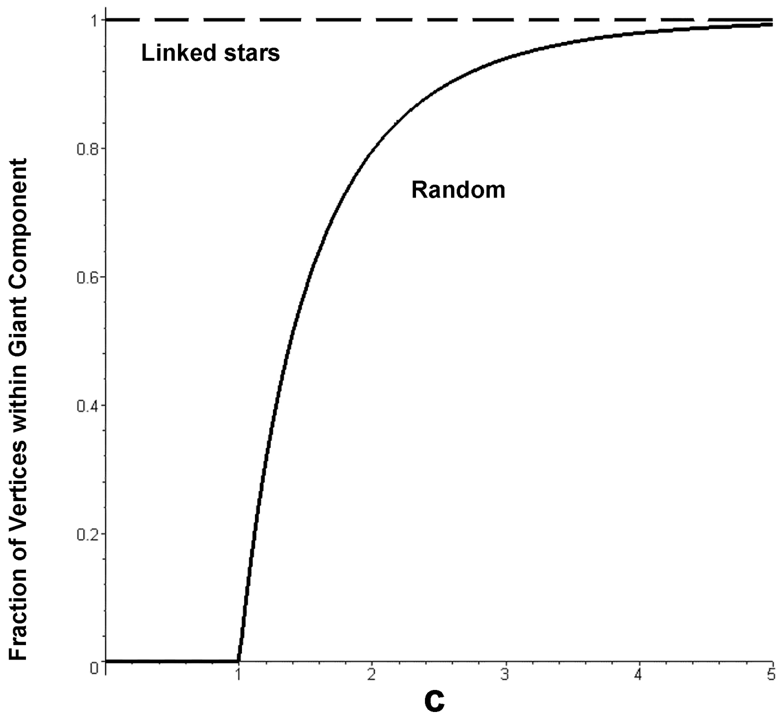

Figure 1: Fraction of network nodes in the giant component as a function of the coupling parameter c. The solid line represents a random graph, the dotted line a star-of-stars-of-stars network in which all nodes are interconnected. Only for the random network, when $c < 1$, is 'herd immunity' possible.

serial forced migration responsible for the disorganization of urban minority communities in the US.

Such a 'behavioral code' perspective is consonant with any number of anthropological studies. Aggleton et. al. (1994), for example, write

> Although sex has a biological function, it is one of the most socially diverse of human activities, and although sexual behavior has a certain biological similarity across the globe, the meaning of sex differs profoundly between cultures and even within societies. This means that the role and purpose of the 'same' biological act may be seen quite differently from culture to culture...
>
> A number of factors other than risk perception influence the extent to which an individual will consistently take steps to protect against infection... in many contexts, the scope for individual decision-making is limited by the greatly under-recognized fact that behavioral change is not solely dependent on individual volition. The relevance of social factors that contribute to risk behavior and the importance of modifying these social factors to enable HIV risk reduction are greater than in almost all other fields of health and behavior...

4 Discussion and conclusions

Marginalization and oppression – the essence of the power relations between groups in Western culture – act synergistically to produce both social network topologies and behavioral codes that constitute risks for the transmission of pandemic infection under a broad spectrum of circumstances. For AIDS in particular, that synergism seems capable of producing a condition of 'herd infection' within African-American and Gay male subgroups that often makes a single behavioral lapse a death sentence. The 'pharamceuticalization' of AIDS in the US – the view that drug treatment of infected individuals constitutes a population-level control strategy – guarantees the evolution of multiply-drug-resistant varieties of HIV in oppressed communities, given the nature of the virus as a relentless evolution machine (Wallace et al., 2009, Section 6.3). MDR-HIV will inevitably diffuse outward from these centers of chronic infection to become a scourge even for those who create, endorse, or tolerate the social conditions producing the fatal synergism we have examined: One possible evolutionary route for HIV is a deadly change in life history strategy that will not see infection confined to marginalized populations in Western societies (R.G. Wallace, 2004).

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